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MEMORANDUM

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DATE: 5-6-49
M-831

TO: F. F. Collbohm

FROM: J. E. Lipp

SUBJECT: COMMENTS ON SKIN FRICTION ASSUMPTIONS DISCUSSED IN NORTH AMERICAN REPORT AL-601, entitled "Comparison of Glide-Rocket and Ramjet Missiles" by Harold W. Bell

Copies to: [illegible]

A short North American report compares glide rocket and ramjet performance under two skin friction assumptions: incompressible and compressible. There is no question that at high speeds some compressibility effect exists in skin friction; it is rather the amount of the compressibility effect which is the subject of this discussion.

The amount of compressibility effect in <u>laminar</u> flow skin friction is well known and accepted because a good theory exists here. On the other hand no turbulent flow theory exists; only empirical formulae for incompressible flow are well established.

The [illegible] flow theory suggests a correction for compressibility in turbulent flow. This arises as follows: If one compares the [illegible] incompressible flow skin friction equations, one finds that [illegible] which depend on temperatures in the incompressible [illegible] equation are re-interpreted the incompressible [illegible] may be used for all speeds. The interpretation made is that instead of using free-stream temperature to determine the temperature dependent properties (namely, density and viscosity) in the laminar flow equation, an "effective" temperature dependent on wall temperature, free stream temperature and Mach number is used. This "effective" temperature approach is now well known in the literature and is used by RAND's Missiles Division. The use of this temperature in laminar flow <u>suggests</u> that it be used also in turbulent flow. Below Mach number of 5 the use of the "effective" temperature gives essentially the same result as the use of the wall temperature which itself is essentially the stagnation temperature. The use of this latter temperature in skin friction was first suggested by von Karman since it was reasonable to assume these properties by "local" values rather than free stream values. This von Karman interpretation is the compressible skin friction referred to by North American. This compressibility interpretation is equivalent to a Mach number correction (stagnation temperature is dependent only on Mach number) which reduces the value of skin friction below that derived from the incompressible [illegible].

The use of the von Karman interpretation below Mach number of 5 rather than the better to use the "effective" temperature, a more [illegible] approach) is verified by two types of experimental information: heat transfer and skin friction.

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The heat barrier tests are those of V-2 flights made by General [illegible]. Results are reported in Hermes Progress Report No. 42.

Much of the friction data we are collecting, obtained in major wind tunnels such as Langerfield and Ames for various contractors such as Douglas verify the von Karman assumption by indirect friction drag calculation. A few direct measurements such as those reported by United Aircraft Meteor Report No. 17 show flat plate skin friction values which agree with the assumed compressible skin friction.

It may be pointed out that while the comparison of the ramjet performance with two skin friction assumptions in the North American report is probably correct, the comparison of the two rocket performance is unfair. This is due to the fact that rocket flight is largely in laminar flow, for which there exists no doubt concerning the correct treatment of compressibility effects on skin friction. The North American comparison based upon incompressibility in laminar flow disregards this fact entirely.

J. E. Lipp

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